

5

## A plate heat exchanger

### THE BACKGROUND OF THE INVENTION AND PRIOR ART

10

The present invention refers to a plate heat exchanger including a number of heat exchanger plates, which are arranged beside each other and connected to each other by means of a braze connection, wherein the heat exchanger plates substantially are manufactured in stainless steel containing chromium, wherein the plate heat exchanger includes a number of port channels extending through at least some of the heat exchanger plates, and wherein one or more of the port channels are surrounded by a connection surface for connection of the port channel to a pipe member.

20

The invention also refers to a method for manufacturing a plate heat exchanger including a number of heat exchanger plates, which substantially are manufactured in stainless steel containing chromium, and including a number port channels extending through at least some of the heat exchanger plates, wherein each port channel is surrounded by a connection surface for connection of the port channel to a pipe member.

25

The heat exchanger plates in plate heat exchangers are frequently manufactured in stainless steel for resisting attacks from various media transported through the heat exchanger. These media may frequently be aggressive against metallic materials. The heat exchanger plates are connected to each other by brazing during a braze process with a braze material based on e.g. copper, nickel, iron or silver. The braze process is

35

normally performed in a closed space at vacuum-like pressure conditions or a gas atmosphere, and at a relatively high temperature, for instance about 1100°C with copper as braze material and about 1200°C with nickel as braze material.

5

In order to connect the channels of the plate heat exchanger to external media-conveying conduits, it is often desirable to braze various types of pipes and conduits to a connection surface of the plate heat exchanger around the port channels. However, it is difficult to braze to stainless steel containing a relatively high percentage of chromium, for instance above 12 percent. According to one theory, this difficulty depends on the fact that the surface layer of the stainless steel contains a high percentage chromium dioxide. In order to make the braze attach to the stainless steel, it is necessary to reduce the chromium dioxide. Chromium dioxide is however difficult to reduce by common fluxing agents having a small toxicity or aggressiveness but it is necessary to make use of more aggressive and toxic fluxing agents, for instance fluxing agents containing fluorine. It would thus for environmental and health reasons be necessary to perform also the brazing of said pipe member in a closed space.

10

15

20

## SUMMARY OF THE INVENTION

25

The object of this invention is to remedy the problems mentioned above. More precisely, the object is to provide a plate heat exchanger offering improved possibilities to attach connection conduits by means of brazing.

30

This object is achieved by the plate heat exchanger initially defined, which is characterised in that the connection surface includes a material that permits brazing of said pipe member to the connection surface in a more easy manner than to stainless steel.

35

By providing the plate heat exchanger with such a material at the port channels, pipe members, such as external conduits, may in an easy manner be connected to the respective port channel through a braze process that may be performed during normal surrounding conditions. It is thus possible to perform these connections at an arbitrary location, for instance where the plate heat exchanger is to be used. Advantageously, said material is more reduction susceptible than chromium dioxide, i.e. the oxide formed on the material may be reduced in a more easy manner than chromium dioxide, and thus strong and reliable braze joint is achieved by easy means. Suitable materials are based on or include one of the materials copper and nickel.

According to an embodiment of the invention, said braze connection of the heat exchanger plates is achieved through a braze process. The braze process may be performed in vacuum or in a gas atmosphere consisting substantially of an inert gas or a reducing gas. Furthermore, said material may be bound to the stainless steel through diffusion, wherein said diffusion is achieved during said braze process. Thanks to such a diffusion of atoms from the material into the steel, and from the steel into the material, a strong metallic bond is achieved.

One of said heat exchanger plates forms an outer heat exchanger plate which has a respective outer surface surrounding a respective port channel. According to a further embodiment of the invention, said material may be applied to the outer surface for forming said connection surface. In this case the connection surface is thus formed directly on the outer heat exchanger plate which is designed to permit brazing of a connection pipe.

According to another embodiment of the invention, the plate heat exchanger includes a connection member at each port channel, wherein the connection member forms said connection

surface. Advantageously, the connection member is attached to the outer surface area. The connection member may have a primary surface onto which said material is applied for forming said connection surface. Also in this case, said material may be  
5 applied on the primary surface and bound to the connection member by diffusion achieved during said braze process.

According to a further embodiment of the invention the primary surface has a rough surface finish, which is accomplished by  
10 abrasive blasting or any similar roughening process and which facilitates wetting of the primary surface with said material. Advantageously, said material may then have been applied onto the primary surface by means of and during the braze process, wherein the material due to the roughened surface will flow out  
15 and be distributed over the primary surface. The connection member may substantially be manufactured in stainless steel containing chromium.

According to a further embodiment of the invention, the  
20 connection member is manufactured in an alloy substantially containing copper and nickel. The connection surface will then be formed by this alloy which on the surface oxidises to nickel oxide and copper oxide, both of which are relatively easily reducible. It is suggested that said alloy may contain 55 to 95  
25 percent by weight copper and 5 to 45 percent by weight nickel, In particular 70 to 80 percent copper and 20 to 30 percent nickel.

According to a further embodiment of the invention, the  
30 connection member is designed as a pipe nipple, wherein the substantially cylindrical inner or outer surface of the pipe nipple forms the connection surface. Alternatively, the connection member may be designed as a washer.

35 The object is also achieved by the method initially defined, which includes the steps of:

applying a material, which forms the connection surface and which permits brazing of said pipe member to the connection surface in a more easy manner than to stainless steel, arranging the heat exchanger plates beside each other, and  
5 joining the heat exchanger plates to each other by means of a braze connection.

Preferred embodiments of the method are defined in the dependent claims 20 to 30.

10

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention is now to be explained more closely by means of various embodiments and with reference to the drawings  
15 attached.

Fig. 1 discloses schematically a plan view of a plate heat exchanger according to a first embodiment of the invention.

Fig. 2 discloses schematically a side view of the plate heat exchanger in Fig. 1.

Fig. 3 discloses schematically a plan view of a plate heat exchanger according to a second embodiment of the invention.

Fig. 4 discloses schematically a side view of the plate heat exchanger in Fig. 3.

Fig. 5 discloses schematically a plan view of a plate heat exchanger according to a third embodiment of the invention.

Fig. 6 discloses schematically a side view of the plate heat exchanger in Fig. 5.

## DETAILED DESCRIPTION OF VARIOUS EMBODIMENTS OF THE INVENTION

35 Figs. 1 to 6 disclose different embodiments of a plate heat exchanger. The plate heat exchanger includes in all

- embodiments a number of heat exchanger plates 1, which are arranged beside each other to form a plate package 2. Each heat exchanger plate 1 includes in a manner known per se a corrugation 3 for increasing the heat transfer, and four port holes for forming a corresponding number of port channels 4 extending through the plate package 2. It is to be noted that the plate package 2 may include another number of port channels 4 than the four disclosed in the embodiments in Figs. 1 to 6.
- 10 The plate package 2 includes a first outer heat exchanger plate 1' and a second outer heat exchanger plate 1''. Between these heat exchanger plates the remaining heat exchanger plates 1 are arranged. In the embodiments disclosed, the first outer heat exchanger plate 1 has also been provided with port holes aligned to the port channels 4, whereas the second outer heat exchanger plate 1' does not have any port holes. The heat exchanger plates 1, 1', 1'' are arranged in such a way that they extend substantially in parallel to a common main extension plane p.
- 20 The heat exchanger plates 1, 1', 1'' are substantially manufactured in stainless steel containing chromium. The chromium percentage means that the surface layer of the heat exchanger plates 1, 1', 1'' will contain chromium dioxide which is difficult to reduce. The heat exchanger plates 1, 1', 1'' are connected to each other by means of a braze connection. The brazing takes place by means of a braze material based on or containing copper, nickel, iron or silver and possibly any possible flux agent that can contain fluorine and that enables reduction of chromium dioxide. A thin foil of the braze material is positioned in each interspace between the heat exchanger plates 1, 1', 1''. Thereafter, the plate package 2 is compressed. The compressed plate package 2 may be placed in a closed space (not disclosed), such as a vacuum furnace, during vacuum-like pressure conditions or in a gas atmosphere consisting of a substantially inert gas or a reducing gas, and a

desired braze temperature which may be up to about 1100°C with copper as braze material and about 1200°C with nickel as braze material.

5 A first embodiment of the invention is now to be explained more closely with reference to Figs. 1 and 2. Each port channel 4 is surrounded by a connection surface 5 for connection of the port channel 4 to a pipe member 6, for instance in the form of an external pipe conduit. The connection surfaces 5 are thus  
10 located on the first outer heat exchanger plate 1' which has an outer surface area surrounding each port channel 4. The connection surfaces 5 thus extend substantially in parallel to the main extension plane p of the heat exchanger plates 1, 1', 1'' and have been formed by a material applied to the outer surface area. This material permits brazing of the pipe members 6 to the  
15 respective connection surface in a more easy manner than stainless steel and is more reduction susceptible than chromium dioxide. In particular, this material may be based on or include one of the materials copper, nickel, iron or silver. Possibly the  
20 material may also include a suitable fluxing agent.

According to this first embodiment, the outer surface areas may thus be coated by a thin layer of for instance nickel. The layer may have a thickness which amounts to about 20 to 50 µm. The  
25 layer may be applied by different methods, for instance by melting or chemical or electrolytic plating. This application of the material may advantageously be made prior to the brazing of the plate package 2, and thus before the plate package 2 is subjected to the above-mentioned vacuum/gas atmosphere and  
30 the above-mentioned braze temperature. The nickel material will during this braze process be bound to the stainless steel of the outer surface areas of the first heat exchanger plate 1' in such a way that a very strong bond is achieved through diffusion.

35 It is to be noted that the layer of nickel material also may be applied after the plate package has been brazed according to

the above description of the braze process. Also in this case, nickel or any other material may be applied through melting or chemical or electrolytic plating.

- 5 According to a second embodiment illustrated in Figs. 3 and 4, the plate heat exchanger includes four connection members. In this embodiment, each connection member is designed as a pipe nipple 8. The pipe nipples 8 are attached to the outer surface area at a respective one of the four port channels 4.
- 10 Each pipe nipple 8 is in this embodiment, as well as the heat exchanger plates 1, 1', 1'', substantially manufactured in stainless steel containing chromium. Each pipe nipple 8 has a primary surface on which the layer with the above-mentioned material is applied for forming the connection surface 5. In the
- 15 embodiment disclosed, the primary surface is formed by an outer cylindrical surface of the pipe nipple 8. However, it is also possible to let the inner cylindrical surface of the pipe nipple 8 form the primary surface onto which the layer with material is applied. The pipe nipples 8 may advantageously be applied to
- 20 the plate package 2 before it is brazed. A foil of braze material is applied before said braze process between the pipe nipples 8 and the first outer heat exchanger plate 1', wherein the pipe nipples 8 will be brazed to the first outer heat exchanger plate 1'. The pipe nipples 8 may also be attached by other methods,
- 25 for instance welding.

- According to a first variant of this embodiment, the layer of material is applied in a similar manner as according to the first embodiment described above. Consequently, the primary
- 30 surface may be coated by a thin layer of for instance nickel. The layer may have a thickness which amounts to about 20 to 50µm. The layer may be applied by different methods, for instance melting or chemical or electrolytic plating. This application of the material may advantageously be made prior to the brazing of the
- 35 plate package 2 and the pipe nipples 8, and thus before the plate package 2 and the pipe nipples 8 are subjected to the



above-mentioned vacuum or gas atmosphere, and the above defined braze temperature. The nickel material applied to the primary surface of the pipe nipples 8 will during this braze process be bound to the stainless steel of the primary surface on the pipe nipples 8 in such a way that a very strong metallic bond is achieved through diffusion.

It is to be noted that the layer also may include a material based on copper. In this case it is however important that a braze material with a lower melt temperature than copper is used for the brazing of the heat exchanger plates 1, 1', 1''. During brazing, a braze temperature that is lower than the melt temperature of the material applied to the pipe nipples 8 has to be used since this material must not melt and flow away from the pipe nipples 8.

According to a second variant of the second embodiment, the primary surface is provided with a rough surface finish. This rough primary surface may be accomplished by blasting or any similar roughening method. The roughening is made as an initial step before the pipe nipples 8 are mounted to the plate package 2. Such a rough primary surface facilitates wetting with the mentioned material and means that the material during the above described brazing of the plate package 2 will flow out over the primary surface in such a way that a strong layer of the material is formed on the primary surface. This layer, which thus may include any of the materials copper, nickel, iron or silver, may also have a thickness of about 20 to 50  $\mu$  and form a connection surface 5 with proper braze properties. Different types of pipe members 6 may then be brazed to this connection surface 5 by means of simple, conventional braze methods.

A third embodiment is illustrated in Figs. 5 and 6. This embodiment also includes four connection members, one around each port hole 4. In this embodiment, each connection member is however designed as a washer 9. The washers 9 are attached

to the outer surface area of the outer heat exchanger plate 1' at a respective one of the port channels 4. Each washer 9 has an outer plane surface forming a substantially plane connection surface 5 to which a pipe member 6 may be attached in a similar manner as in the embodiment disclosed in Figs. 1 and 2. Furthermore, each washer 9 in this embodiment is manufactured in an alloy containing mainly copper and nickel. By the addition of nickel to copper the melt temperature of the alloy may be increased, the higher percentage of nickel the higher the melt temperature. Preferably, the alloy is to contain only so much nickel that the melt temperature becomes higher than the melt temperature of the braze material used for brazing the plate package and for brazing the washers 9 to the outer heat exchanger plate 1'. For instance the alloy may contain 55, 60, 65, 70, 75, 80, 85, 90 or 95 percent by weight copper and a corresponding percentage nickel, i.e. 5, 10, 15, 20, 25, 30, 35, 40 or 45 percent by weight nickel. The washers 9 may as well as in the embodiment disclosed in Figs. 3 and 4 be attached in various ways to the outer heat exchanger plate 1'.

It is to be noted that the connection members which are manufacture in stainless steel and which are disclosed in Figs. 3 and 4 as an alternative may be designed as washers 9 and that the connection members manufactured in an alloy of copper and nickel and disclosed in Figs. 5 and 6 as an alternative may be designed as pipe nipples 8. Also other shapes of the disclosed connections member than pipe nipples 8 and washers 9 are possible.

The invention is not limited to the embodiments disclosed but may be varied and modified within a scope of the following claims.